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## 4 Casting Bed

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**Concrete Forms**

**Reinforcing**

**Splices**

**Prestressing**

**Elongation**

**Prestressing System**

**Initial Tensioning of Straight Strands**

**Initial Tensioning of Draped Strands**

**Up-Lift and Hold-Down Devices**

**Strand Splices**

**Measuring Elongation**

*Example Computations for Elongation*

**Temperature Variations**

*Example Computations for Temperature Correction*

**Slippage of Strand Anchors**

**Movement of Anchorage Abutments**

**Elongation of Abutment Anchoring Bolt**

# CHAPTER FOUR:

## *CASTING BED*

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The Technician is required to check the casting beds periodically for deviations from a plane surface. Any deviations sufficient to cause irregularities in the bearing areas of the member, or other irregularities that may approach or exceed the established tolerances are required to be corrected.

### CONCRETE FORMS

Precast prestressed structural members are generally manufactured in steel forms. The interior of the forms are thoroughly cleaned after each use and are required to be treated with an approved formulated form coating prior to placing concrete. Some concrete will remain on the bottom flanges of the forms after removal of the structure member which may appear as an irregularity on the next beam. The tops of the forms are also required to be kept clean of any possible contaminants during the pour. Form coating materials are required to be free from lubricating oils, fuel oils, kerosene and other ingredients which cause discoloration of the finished concrete and are required to be applied before any reinforcing bars or prestressing strands are placed in the forms. Since the integrity of all pretension members is based on the development of uniformly high bond on all strands and reinforcing, the necessity of clean strands and reinforcing is important. Form ties, if used, should be of either the threaded type or snap-off type so that no form wire or metal pieces are left at the surface of the finished concrete.

Voids in the structure members may be formed by any material. Materials, such as polystyrene, are required to be firmly anchored to prevent floating or movement during the placement and compaction of the concrete. Improper location of the voids will change the structural properties of the member and may easily result in a weak member. Void tubes may be held in position by the use of metal fittings (saddles or chairs) placed permanently on top or by the use of tie wires and spacer templates. The spacer templates are required to be removed after the tubes are securely fastened by tie wires or immediately after placing the concrete and before the concrete has set. Spacer templates or other positioning devices that may have a tendency to induce cracking in the finished structure member if left in place, are required to be removed before, during, or immediately after the concrete is placed. Other methods of satisfactorily holding the tubes in place may be used. Any method to position and hold void tubes in the correct location is required to not affect the vertical or horizontal alignment of the prestressing strands.

When two or more sections of void tubes (cylindrical or rectangular) are used to make up a required length, the ends are effectively taped together. Forms for void tubes damaged during storing, exposure to the elements, or handling are not used. Cylindrical void tubes are placed longitudinally side by side. The usual dimensions

for these tubes are 10 ½ in. outside diameter for standard 17 in. structural member depth and 12 ½ in. outside diameter for standard 21 in. structural member depth. If cylindrical void tubes are positioned before the start of concreting operations, adequate precautions are required to be taken to insure that no movement occurs during placement and consolidation of the concrete.

Rectangular void tubes are required to be of the sizes specified on the Standard Drawings or approved Shop Drawings and the interior corners are required to be chamfered as specified or approved. The void tubes are placed after the concrete is struck off accurately to the thickness of the bottom slab to eliminate the possibility of void spaces beneath the tubes.

All necessary provisions to ensure the proper positioning of the voids in the finished member is the responsibility of the Fabricator. In addition to other checks, the Technician is required to verify that the tubes are placed correctly and remain in the correct position. The Technician also is required to check the location, position, and condition of the void drains. The voids are to be vented during the curing period.

Any and all voids are subject to a position check after the structural members have been constructed. Any structural member with a void out of position in excess of the specified tolerances may be rejected.

## **REINFORCING**

Reinforcing bars, wire reinforcement, and prestressing strands are required to be stored under cover and protected at all times from damage.

Reinforcement required to be bent shall be accurately cold bent in a bending machine to the shapes shown on the plans. Reinforcing bars with cracks or splits are required to be rejected. All dimensions shown on the plans for spacing of reinforcing bars apply to centers of bars unless otherwise noted. Reinforcing bars are accurately placed and firmly anchored to retain their position as shown on the plans during concrete placement. Distances from the forms are maintained by means of chairs, ties, hangers, or other approved supports. All reinforcement is required to be rigidly wired or securely fastened at sufficient intervals to hold the reinforcement in place. Welding reinforcing bars is not allowed.

Layers of bars are required to be separated by approved spacers. Reinforcing bars are separated from horizontal surfaces by being suspended or supported on approved metal chairs and spacers. For the steel reinforcement near the header in Figure 4-1, the reinforcing bars are spaced closely together near the ends of the member. The chairs maintain the proper spacing between the rebar and the forms when the bed is closed and the concrete is poured. The stirrups are placed around the prestressing strand. The strands in the vertical position are the lifting loops.



**Figure 4-1. Metal Chairs and Spacers**

Metal supports and spacers are of such shape that they may easily be encased in concrete, and that portion of the support and spacer in contact with the forms is required to be non-corrosive and non-staining material. The supports and spacers types are approved by the Engineer. Vertical stirrups always pass around main tension members and are required to be securely attached. The use of pebbles, broken stone or bricks, metal pipe, wooden blocks or other similar devices for holding reinforcement or strands in position is not permitted.

After being placed, all reinforcement is inspected and approved before the concrete is placed. The positions of the bars, both during and after the placement of the concrete, may not be altered.

## **SPLICES**

All reinforcing bars are required to be furnished in the full lengths indicated on the shop plans unless splices are indicated. No other splicing is allowed, except with written permission of the Engineer.

For lapped splices (Figure 4-2), reinforcing bars are required to be placed in contact and rigidly clamped or wired in a manner approved by the Engineer. Unless otherwise shown on the drawings, reinforcing bars are to be lapped at 32 times the bar diameter to make a splice. If possible, splices are required to be staggered and well distributed, or located at points of low tensile stress. Splices are not permitted at points where the section does not provide a distance of at least 2 in. between the splices and the nearest adjacent bar or surface of the concrete unless indicated otherwise on the design or approved shop drawings. Laps are required to be in accordance with **703.06**.



**Figure 4-2. #6 Reinforcing Bar lapped, spliced, and tied into place along the top of the structural member**

## **PRESTRESSING**

Prestressing strands are carefully handled at all times to prevent kinks, nicks, bends, or other defects. The use of prestressing strands with these defects is not permitted. Tensioned strands are subject to relaxation if subjected to excessive temperatures such as those produced by torches, welding equipment, or sparks and are required to be protected accordingly. The strands are required to be the type, size and number specified and be located and spaced as shown on the detail design or shop drawings. Each reel of strand is labeled (Figure 4-3).



**Figure 4-3. Reels of Strand**

## ELONGATION

In all methods of tensioning, the stress induced in the prestressing strands is required to be measured both by gauges and by elongation of the tendons or strands (Figure 4-4).



**Figure 4-4. Elongated Strands**

The elongation for the gauge length of the strand is computed accurately using the actual cross-sectional area and modulus of elasticity of the strand from the laboratory report and the design load for each strand from the plans. The computed elongation and the design load are adjusted to compensate for any operational losses or thermal corrections. Form IC 737 (Appendix A), is used for computing the elongation. The strands are tensioned to the adjusted design load.

The actual elongation obtained on each strand is checked against the adjusted computed elongation and is required to be within the allowable tolerance of five percent. The strands are required to be held securely in place and, where necessary, galvanized chairs or other approved methods are used to prevent sag of the strands and to assure the thickness of the concrete beneath the strands is as shown on the drawings.

Draped strands, when specified, are required to be deflected at the third points (Figure 4-5) or at the locations shown on the detail design drawings or approved shop drawings. Strands are securely held in place at all points of change in slope with a roller device that minimizes friction during tensioning.





**Figure 4-5: Tensioned Straight Strands and Deflected Strands**

Pre-tensioning may be done by prestressing one strand or by tensioning two or more strands simultaneously. An orderly procedure of stringing and tensioning the strands is important for easy record keeping.

## **PRESTRESSING SYSTEM**

The prestressing system (Figure 4-6) used by the Fabricator is equipped with accurately calibrated gauges for registering the loads produced. A record of the force applied to each prestressing strand and the identification of the prestressing strand and unit to which the record applies is made. All readings are placed on form IC 736 (Appendix A). Pressure gauges, load cells, dynamometers, or other devices may be used. All devices for measuring the stressing load are required to have a reading accuracy within two percent. All gauges are required to be calibrated annually by an approved laboratory. If during the progress of the work any gauging system appears to be giving erratic results, the jack and the gauges are required to be re-calibrated. The laboratory shall furnish a calibration curve for each device indicating errors or adjustments necessary over the entire span of the gauge. Gauges are required to have a reading dial of not less than 8 in. in diameter and digital readouts, if used, should be easily read.





**Figure 4-6: Prestressing System**

Each gauge is capable of reading loads directly in pounds or is accompanied by a chart from which the dial reading may be converted to pounds. Calibration of gauges is required to be done with the gauges on the jacking system to be used in the prestressing operations. The load shall be acting on the ram of the jack and in the same direction as the actual tensioning operation. The gauges are required to have a full pressure capacity of approximately twice the working pressure. Unless calibration data clearly establishes accuracy over a greater range, the loads to be gauged are required to be not less than 1/4 or more than 3/4 the total graduated capacity of the dials. A tensioning system using hydraulic gauges shall have appropriate by-pass piping valves and fittings, such that the gauge point remains steady and does not fluctuate until the jacking load is released from the strand. Gauges shall be mounted at near working eye level and within 6 ft of the operator to insure accurate and consistent readings.

## **INITIAL TENSIONING OF STRAIGHT STRANDS**

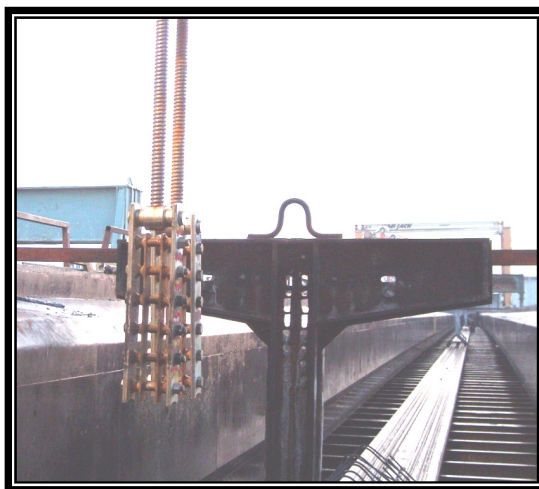
The purpose of the initial tensioning is to take up the slack in the strands so that elongation measurements may be made during final tensioning. After the prestressing strands have been positioned, a minimum initial tensioning force of 1000 lb is required to be applied to each strand to be tensioned to equalize the stresses in the strands. This may be increased if necessary; however, the tensioning force shall not exceed a value of 5000 lb. The magnitude of the initial tensioning force is the minimum force necessary to equalize the stresses and eliminate slack in the strands. The standard method used to apply the initial tensioning force is a single strand tensioning jack which is the same jack used for single strand tensioning. The jack is required to be equipped with a gauging system that registers the initial tension force. The length of the casting bed and the number and size of the strands tensioned determines the magnitude of this force. Elongation measurements are not used to determine the initial tensioning force. Properly calibrated load cells may be used for this purpose.

The initial tensioning sequence for a group of strands is required to be such that the indicated tensile force is uniformly distributed in the strand throughout the length. The strand being tensioned may not be restrained by exterior forces. Where the strand passes through the stirrups, spirals, or headers, care is necessary to prevent binding that would result in substantial restraint. Avoiding entanglement of the strands during tensioning may be accomplished by having a definite sequence of laying and tensioning. In most cases, the laying of the strands shall progress from the bottom row of the strand group to the top row. The initial tensioning is done in the reverse order.

When single strand jacking is used, the jacking ram has a tendency to rotate due to the unwinding action of the strand. This rotation is required to be minimized as considerable losses in the strand tension may occur if unwinding in excess of one turn is permitted.

### **INITIAL TENSIONING OF DRAPED STRANDS**

Draped pre-tensioned strands are tensioned entirely by jacking with the strands held in their draped position by means of rollers (Figure 4-7) or other approved methods during the jacking operation. The low-friction free turning rollers are required to be used at all hold-up and hold-down points where there is a change in slope of the strand trajectory. The roller devices that hold up the strand are located outside of the headers and may be adjusted vertically to correspond with the dimensions specified on the plans. The tensioning of draped strands applied by jacking is done by the same procedures and is required to conform to the same requirements as the tensioning for straight strands. Any other method used for tensioning draped strands is required to be indicated on the shop drawings and approved by the Designer of Record.



**Figure 4-7. Rollers**

Draped strands are pulled through the abutment plate on one end of the casting bed. Once the strand is properly spaced through the hold-down and hold-up points, chucks (Figure 4-8) are put into place and then prestressing may begin.



**Figure 4-8. Strand Chucks**

The required procedure for tensioning draped strands in the deflected position by single strand jacking is as follows:

- 1) Apply the initial tensioning load to the strand
- 2) Mark the strand for elongation measurement
- 3) Apply the full tension load as determined by the jack gauge, not by elongation
- 4) Measure the elongation and determine the remaining elongation required for full tension based on computed elongation
- 5) Apply the full tension load to the other end of the strand and measure the elongation at that end. The sum of the two elongation measurements from each end is required to be within the allowable tolerance of 5 percent.

The strand may be tensioned simultaneously at each end to the full tension load and the elongation measured at each end. The sum of the two elongation measurements are required to be within the allowable tolerance.

Single strand tensioning of the strands in the draped position by jacking the strands from only one end is permissible for shorter beds provided the strand elongation obtained is within the allowable tolerances and the required load on each strand is not exceeded.

Friction at each of the positioning devices resists some of the forces exerted in pulling the strands. The load actually applied to the strand, therefore, is decreased at each successive point of deflection away from the sources of pull. When several members are to be cast on the same bed and tensioning is performed from both ends involving a large number of positioning devices, the loss of stress in the strand away from the source or sources of pull may be excessive. This is evident by undue disagreement between the load determined by the elongation measurement and that indicated by the gauges. When this situation occurs, the number of points of deflection is required to be reduced sufficiently so that the friction losses do not influence the tensioning beyond the five percent allowable tolerance.

The lengths of the strands to be used in calculating elongations will be the actual length of the strand along the trajectory between the fixed anchorage and the referenced point at the jacking end of the strand.

## **UP-LIFT AND HOLD-DOWN DEVICES**

Up-lift and hold-down devices (Figure 4-9) are attached in such a manner to maintain the specified center to center spacing of strands in both the vertical and horizontal directions. Provisions are made for the opening left by the removal of the restraining device to be grouted. Using aluminum sleeves or approved fiber sleeves for the hold-down bolts is satisfactory (Figure 4-10).



**Figure 4-9. Hold – Down Device**





**Figure 4-10. Aluminum Sleeves**

## **STRAND SPLICES**

The splicing of straight strands in accordance with AASHTO M 203 is permitted. Splice locations may not fall within the concrete member. Splices are preferred to be located on the end opposite the hydraulic jack referred to as the "dead" end. Spliced strands are required to have the same "twist" or "lap". For single strand tensioning, slippage of the splices is considered in computing the elongation.

When tensioning multiple strands, either all of the strands or not more than 10 percent are required to be spliced since correction for excessive slippage of individual strands cannot be made. If all of the strands are spliced, the average splice slippage is considered in computing the elongation. Splices may only be made between the beams and not in the middle. If 10 percent or less of the strands are spliced, no slippage allowance is required. Splicing is not permitted on draped strands.

While prestressing operations are in progress, the Technician is required to check the gauges indicating the tension load and check the elongation to assure that the strand is not fowling or unwinding beyond the strand vise. The Technician also checks for slippage in the strand vises and in the strand splices and for any movement of the anchorages or abutments. Section **707** designates the number of permissible wire breaks. Any permissible wire breaks which may occur are located and the ends securely tied to the strand with wire. A strand with a broken wire is tensioned to the same elongation as strands with no broken wires, but not to the same load. The elongation is obtained with approximately 86 percent of the load required for whole strands.

## MEASURING ELONGATION

The degree of accuracy necessary in reading the elongation depends on the magnitude of elongation obtained, which in turn depends upon the length of strand tensioned. Measurements to the nearest 1/8 in. are satisfactory for casting beds of 150 ft or longer and measurements to the nearest 1/16 in. are satisfactory for casting beds shorter than 150 ft.

There may be differences between the adjusted computed elongation and the actual measured elongation. The allowable difference may be up to 15 percent. In the event of a difference in excess of this amount, the entire operation is required to be carefully checked and the source of error determined and corrected before proceeding further.

After the initial tensioning force has been applied to the strand, reference points for measuring the elongation due to additional forces are required to be established. The location of the reference points will vary slightly with the different methods of tensioning strands and with the physical characteristics of the equipment used. The adjusted computed elongation and the plus and minus tolerance limits of 5 percent are accurately determined from these reference points. The actual elongation obtained is then checked against the allowable tolerances.

Calculations for elongation and jacking pressures are required to include the appropriate allowances for thermal corrections, friction, and all possible slippage and relaxation of the anchorages.

### *Example Computations for Elongation*

Assume the problem is to tension 46, 7/16 in. stress relieved strands to a total tension of 19,100 lb for each of four beams 80 ft long. The casting bed has a length of 350.5 ft from the strand anchorage to the reference point for tensioning.

$$\text{Elongation (inches)} = \frac{PL}{AE}$$

P = tension forces in pounds

L = distance in inches from anchorage to reference point

A = cross-sectional area of strand in square inches

E = modulus of elasticity of prestressing strand assumed as 27,500,000 lb/sq. in.\*

\* This value is an average modulus of elasticity applied to the stress range between the initial tensioning and 70 percent of ultimate strength. Where the modulus of elasticity established by the strand manufacturer or the stress range is appreciably different from the example shown, the value of the modulus is more accurately established and approved by the Office of Structural Services.



$$P = 19,100 \text{ lb (total)} - 1,500 \text{ lb (initial)} = 17,600 \text{ lb (net)}$$

$$L = 350.5 \text{ ft.} \times \frac{12 \text{ in.}}{\text{ft}} = 4,206 \text{ in.}$$

$$A = 0.109 \text{ sq. in.} = \text{area of one } 7/16 \text{ in. strand}$$

$$E = 27,500,000 \text{ lb/in}^2$$

$$\text{Elongation} = \frac{17,600 \times 4,206}{0.109 \times 27,500,000} = 24.70 \text{ in. (computed elongation)}$$

Assume 0.25 in. slippage in strand anchorages. Total elongation required after initial tensioning to prestress strand to 19,100 lb is:

$$24.70 \text{ in.} + 0.25 \text{ in.} = 24.95 \text{ in.}$$

## TEMPERATURE VARIATIONS

Changes in the temperature of the strands after tensioning will often result in stress changes in the strands. When strands are stressed in a cold atmosphere and warm concrete is placed around the strand there is a reduction in the tension due to the thermal expansion of the strand. The reverse is true if the strands are stressed on a very warm day and the temperature of the concrete is cooler than the temperature of the strands when tensioned.

When the temperature of the strands being tensioned is 25°F or more below or above the temperature of the placed concrete, the strand elongation and load computations are required to take into account the difference between the temperature of the strands when tensioned and the temperature of the concrete when placed. The Fabricator is required to follow Section **707.07** when required overstressing would exceed 75 percent of the ultimate strength of the strand. The Engineer is informed of this procedure. The amount of strand under tension not subjected to elevated temperatures while the concrete is undergoing the initial set is considered in the computations. Predicting the temperature of fresh concrete with sufficient accuracy to calculate the temperature change expected in the reinforcing at the time the concrete is placed is normally possible.

### *EXAMPLE COMPUTATIONS FOR TEMPERATURE CORRECTION*

#### Prestressing on a Cold Day

Assume for the previous example of elongation computations that the strands are stressed at an air temperature of 25° F and that the concrete at placement was expected to have a temperature of 75° F

$C = \text{Thermal coefficient of expansion of steel} = 0.0000065 \text{ in/in/deg}$

$L_{\text{concrete}} = \text{Length of strand incased in concrete (add length of beams in the bed) is } 3840 \text{ in.}$

$T_1 = 75^\circ\text{F}$  (expected temperature of concrete at time of placement)

$T_2 = 25^\circ\text{F}$  (temperature at which the 4,206 inch strand was tensioned)

Elongation = 24.70 in. (from previous example problem)

Total Elongation (length change) in strand due to higher concrete temperature:

Total Elongation = Elongation +  $C \times (L_{\text{concrete}}) \times (T_1 - T_2)$

Total Elongation =  $24.70 + 0.0000065 \times (3840 \text{ in}) \times (75^\circ\text{F} - 25^\circ\text{F}) = 1.25 \text{ in.}$

Total Elongation =  $24.70 \text{ in.} + 1.25 \text{ in.} = 25.95 \text{ in.}$

Assume 0.25 in. slippage in strand anchors

Total Elongation =  $25.95 \text{ in.} + 0.25 \text{ ins.} = 26.20 \text{ in.}$

When strands are stressed in a cold atmosphere and warm concrete is placed around the strands, there will be a reduction in the tension due to the thermal expansion of the reinforcing.

#### Prestressing on a Hot Day

Similar corrections are made if prestressing is done on a hot day. The temperature of the steel beds may be approximately  $110^\circ\text{F}$  on a warm day while the concrete temperature may be approximately  $70^\circ\text{F}$ . The resulting reduction in the temperature results in an increase of tensile stresses in the prestressing strands.

$C = \text{Thermal coefficient of expansion of steel} = 0.0000065 \text{ in/in/deg}$

$L_{\text{concrete}} = \text{Length of strand incased in concrete (add length of beams in the bed) is } 3840 \text{ in.}$

$T_1 = 110^\circ\text{F}$  (temperature at which the 4,206 in. strand was tensioned)

$T_2 = 25^\circ\text{F}$  (expected temperature of concrete at time of placement)

Elongation = 24.70 in. (from previous example problem)

Total elongation (length change) in strand due to lower concrete temperature:

$$\text{Total Elongation} = C \times (L_{\text{concrete}}) \times (T_1 - T_2)$$

$$\text{Total Elongation} = 0.0000065 \times (3840 \text{ in.}) \times (110^\circ \text{ F} - 70^\circ \text{ F}) = 1.00 \text{ in.}$$

$$\text{Total Elongation} = 24.70 \text{ in.} - 1.00 \text{ in.} = 23.70 \text{ in.}$$

Assume 0.25 in. slippage in strand anchors

Total Elongation = 23.70 in. + 0.25 in (for slippage) = 23.95 in. When strands are stressed in a warm atmosphere and cooler concrete is placed around the strands there will be an increase in the tension due to the thermal shrinkage of the reinforcing.

## **SLIPPAGE OF STRAND ANCHORS**

One of the most frequent causes of discrepancies between calculated and measured elongations is slippage of the gripping devices at either or both ends of the bed. In multiple strand tensioning, one or more grips may slip considerably and not be detected by elongation or load measurement.

One method of detecting slippage is to mark each strand with a crayon or soapstone at a uniform distance of 1/2 in. to 1 in. from where the strand emerges from the gripping device. Movement of the mark shows the slippage. The slippage of the strand in the gripping device at the jacking end of the strand is easily detected after anchoring by determining the loss in measured elongation.

In normal operation, most grips in common use slip from 1/8 in. to 1/4 in. depending on the type and condition of the grips. This means that a correction of as much as 1/2 in. may be necessary in the calculations for elongation. Slight errors in corrections for grip slip are much less significant on the long beds than on short beds. For example, if the anticipated correction is 1/4 in. and the slip is actually 1/2 in., an elongation of 50 percent will be in error less than one percent. However, if the total elongation is 4 in., the 1/4 in. error in anticipated grip slip results in a 6 percent error in total elongation.

Another problem is slow, gradual slippage in gripping devices from the time the initial tensioning is done until the concrete around the prestressing elements has set. The Technician is required to watch for this unusual condition.

## **MOVEMENT OF ANCHORAGE ABUTMENTS**

For each pre-tensioning operation, the yield, deflection, or movement of the anchorage abutments is required to be determined. The value of this measured movement will reasonably compare with the assumed value in the elongation calculations. The significance of the discrepancy between the assumed and measured abutment movement is dependent upon the distance between the anchoring abutments. Usually if the combined movements exceed 1/16 in. per 100 ft of strand length, the need for applying corrections to the measured elongation and applied loads is required. The DTE is required to be consulted for these corrections.

## **ELONGATION OF ABUTMENT ANCHORING BOLTS**

If anchor bolts used in the abutment anchoring system experience tensile stresses during prestressing, the elongation of these bolts is required to be considered in the elongation calculations. After the full tensile load has been applied to these bolts, the actual elongation is measured and compared with the theoretical elongation. The significance of differences in these values is dependent upon the length of the prestressing bed. The DTE is required to be consulted for these corrections.